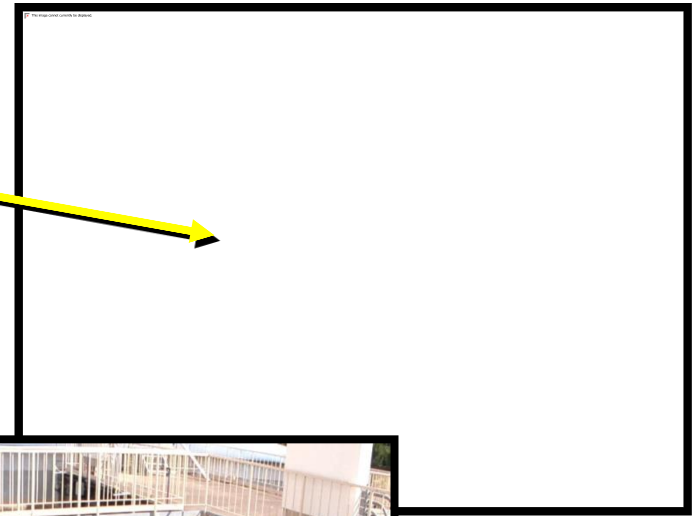
Coagulation-Flocculation-Jar Test

Assoc. Prof. Kozet YAPSAKLI

Turbidity

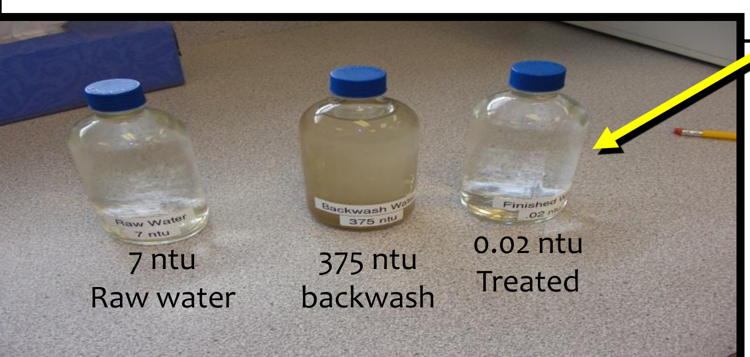
- Turbidity – particles (sand, silt, clay, bacteria, viruses) in the initial source water that need to be removed to improve treatment.

1. Suspended Solids



2. Colloidal Solids (~0.1 to 1 mm)

3. Dissolved Solids (<0.02 mm)



Why coagulation is needed

Various sizes of particles in raw water

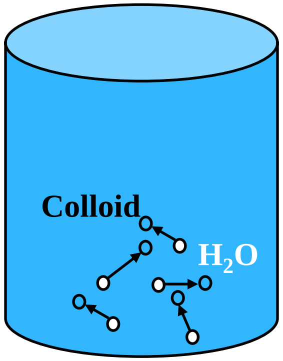
Particle diameter mm	Type	Settling velocity
10	Pebble	0.73 m/s
1	Course sand	0.23 m/s
0.1	Fine sand	0.6 m/min
0.01	Silt	8.6 m/d
0.0001 (10 micron)	Large colloids	0.3 m/year
0.000001 (1 nano)	Small colloids	3 m/million year

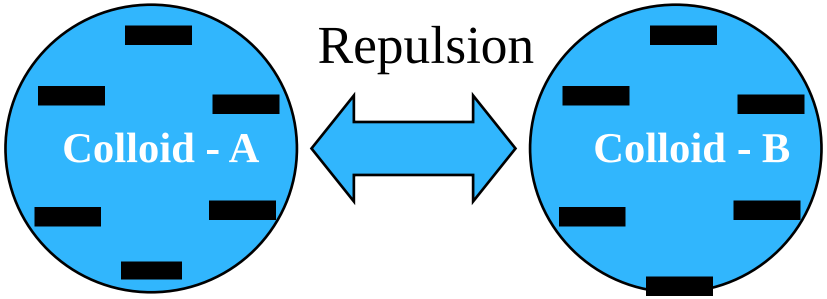
Gravity settling

- ✓ **Colloids – so small, gravity settling not possible**
- ✓ **Metal precipitates are usually colloidal**

Colloid Stability

- ✓ **Colloids have a net negative surface charge**
- ✓ **Electrostatic force prevents them from agglomeration**
- ✓ Brownian motion keeps the colloids in suspension
- ✓ **Impossible to remove colloids by gravity settling**



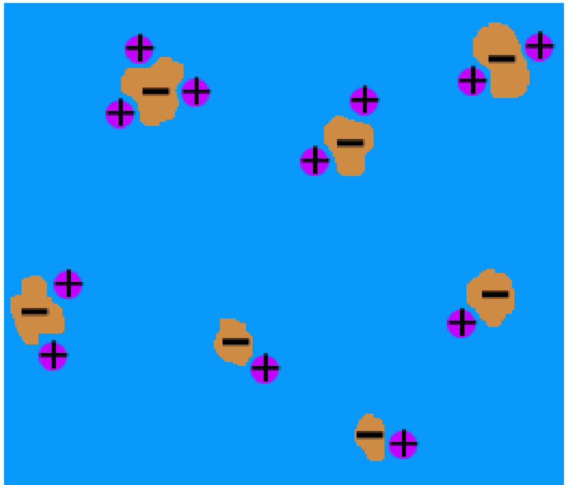


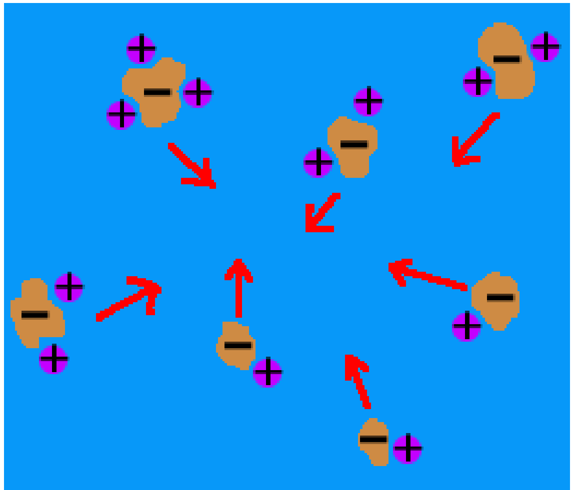
Two primary destabilization methods

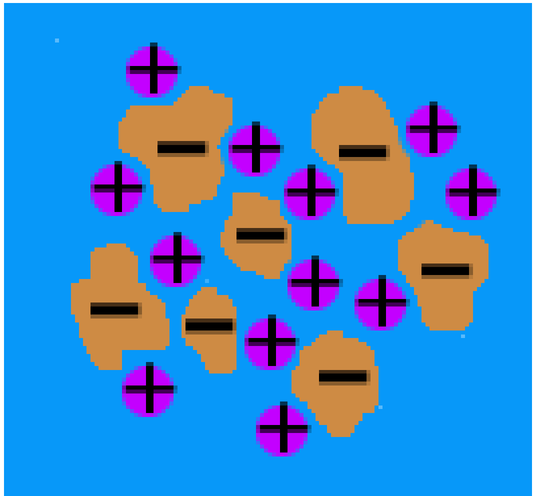
- ✓ **Colloids can be destabilized by charge neutralization :**

  Positively charged ions (Na^+, Mg^{2+}, Al^{3+}, Fe^{3+} etc.) neutralize the colloidal negative charges and thus destabilize them. ✓

- ✓ **With destabilization, colloids aggregate in size and start to settle**







Two primary destabilization methods

✓ **Colloids can be destabilized by sweep flocculation (Enmeshment in a precipitate)**

✓If metal salts, e.g., $Al_2(SO_4)_3$, $FeCl_3$ are added in sufficient quantities to exceed the solubility products of the metal hydroxide, oxide or, sometimes carbonates a "sweep floc" will form. Colloids will become enmeshed in the settling sweep floc and be removed from the suspension.

* Most drinking water treatment plants operate using sweep flocculation
  * requires a higher coagulant dose, rather than charge neutralization.
* In charge neutralization, the positively charged metal coagulant is attracted to the negatively charged colloids via electrostatic interaction.
* Adding excess coagulant beyond charge-neutralization results in the formation of metal coagulant precipitates. These metal hydroxide compounds (e.g., $Al(OH)_3$ or $Fe(OH)_3$) are heavy, sticky and larger in particle size.

Water Treatment Coagulants

Particles in water are negative; coagulants usually positively charged.

1. Alum- aluminum sulfate
2. Ferric chloride or ferrous sulfate
3. Polymers

Coagulant	pH
Ferric sulfate	3.5 to 7.5 and above 9.0
Ferrous sulfate(copperas)	8.5 and above
Ferric chloride	3.5 to 6.5 and above 9.0
Alum	4.0 to 8.0

Water Treatment Coagulant Alum

Alum- (aluminum sulfate)- particles suspended in natural, untreated water normally carry a negative electrical charge. These particles are attracted to the positive charges created by aluminum hydroxides. Dosage is generally around 25 mg/L.

1. Trivalent Al^{+3} charge attracts neg – particles
2. Forms flocs of aluminum hydroxide ($AlOH_3$).
3. Impacted by mixing, alkalinity, turbidity and temp.
4. Ideal pH range 5.8-8.5

Jar Tests

- The jar test – a laboratory procedure to determine the optimum pH and the optimum coagulant dose

- A jar test simulates the coagulation and flocculation processes

Determination of optimum pH

- Fill the jars with raw water sample (500 or 1000 mL) – usually 6 jars

Adjust pH of the jars while mixing using H_2SO_4 or NaOH/lime (pH: 5.0; 5.5; 6.0; 6.5; 7.0; 7.5)

- Add same dose of the selected coagulant (alum or iron) to each jar (Coagulant dose: 5 or 10 mg/L)

Jar Test

- Rapid mix each jar at 100 to 150 rpm for 1 minute. The rapid mix helps to disperse the coagulant throughout each container

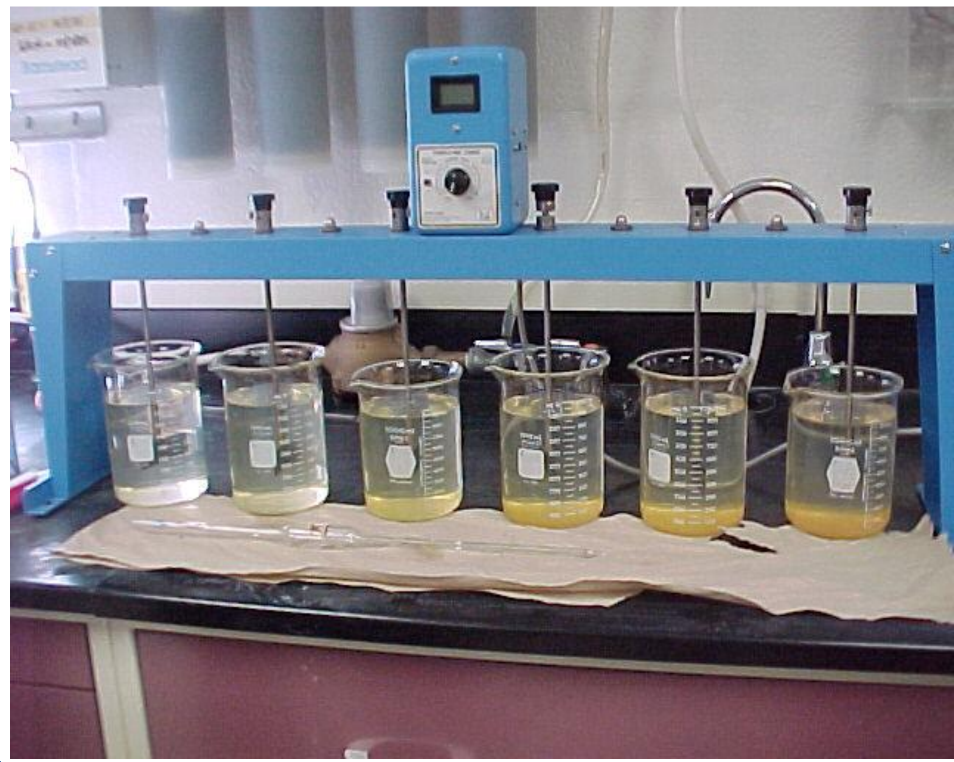
- Reduce the stirring speed to 25 to 30 rpm and continue mixing for 15 to 20 mins

This slower mixing speed helps promote floc formation by enhancing particle collisions which lead to larger flocs

- Turn off the mixers and allow flocs to settle for 30 to 45 mins

- Measure the final residual turbidity in each jar

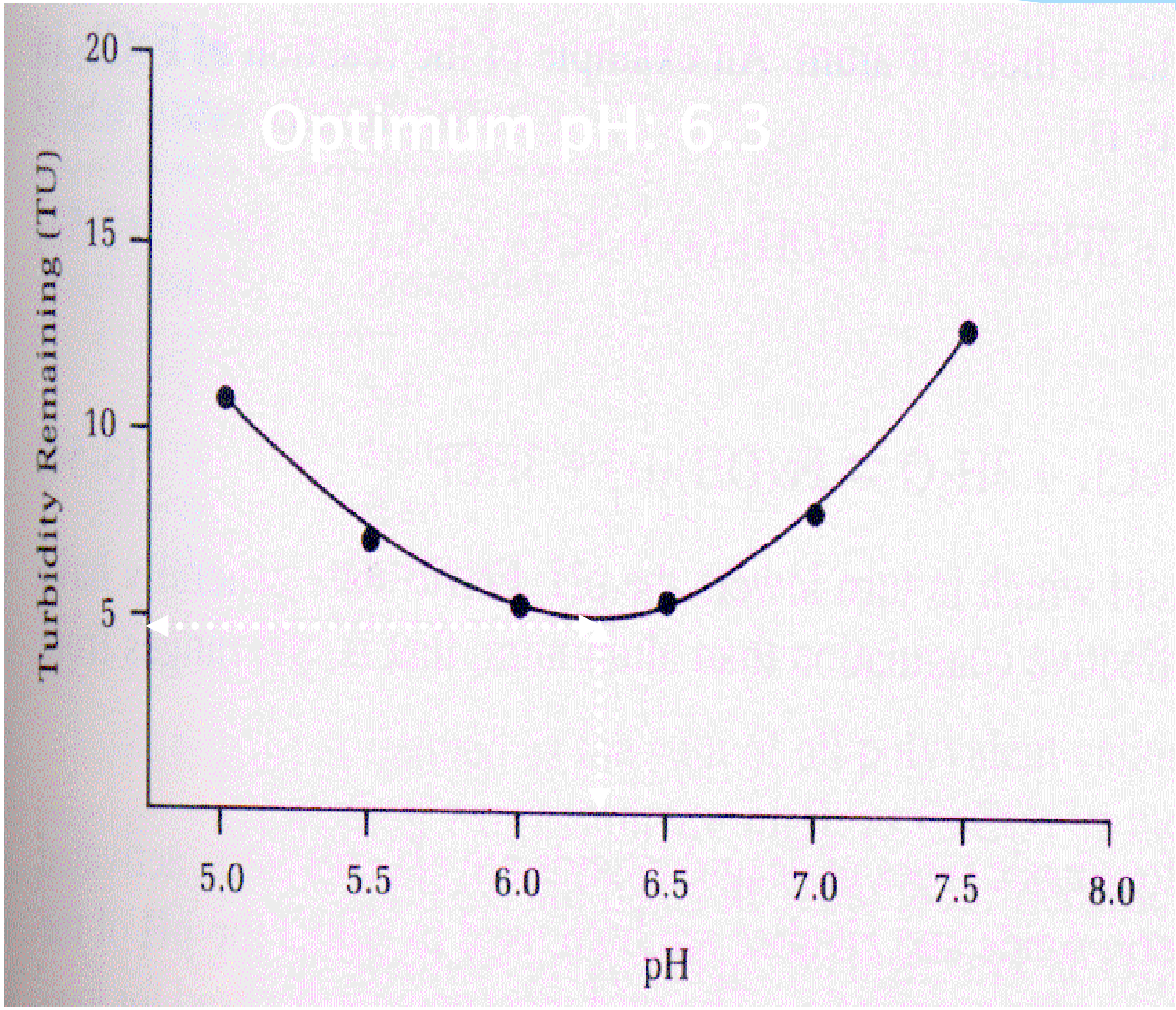
- Plot residual turbidity against pH



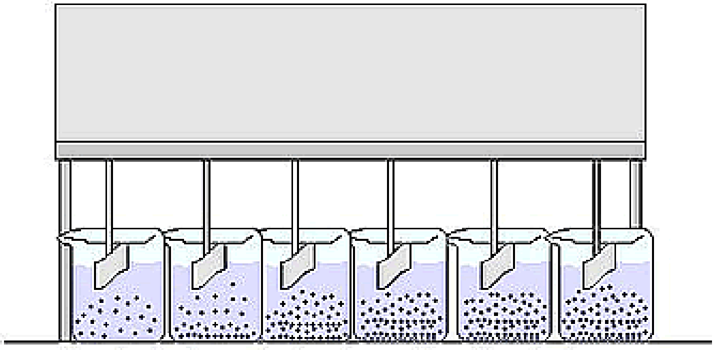
Jar Test set-up

The pH with the lowest residual turbidity will be the optimum pH

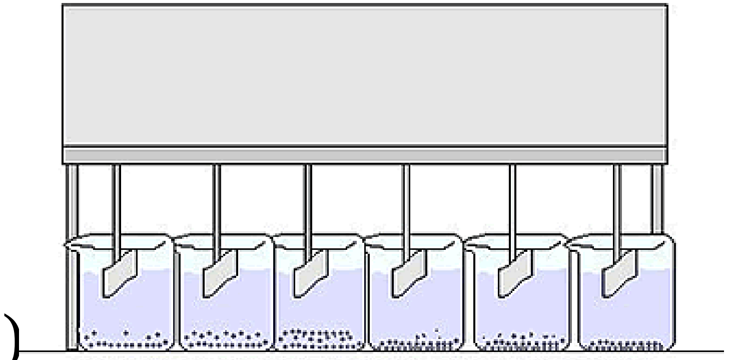
Residual turbidity Versus pH



Determination of optimum coagulant dose



- Fill jars
- Adjust pH of all jars at optimum (6.3 found from first test) while mixing using H_2SO_4 or NaOH/lime

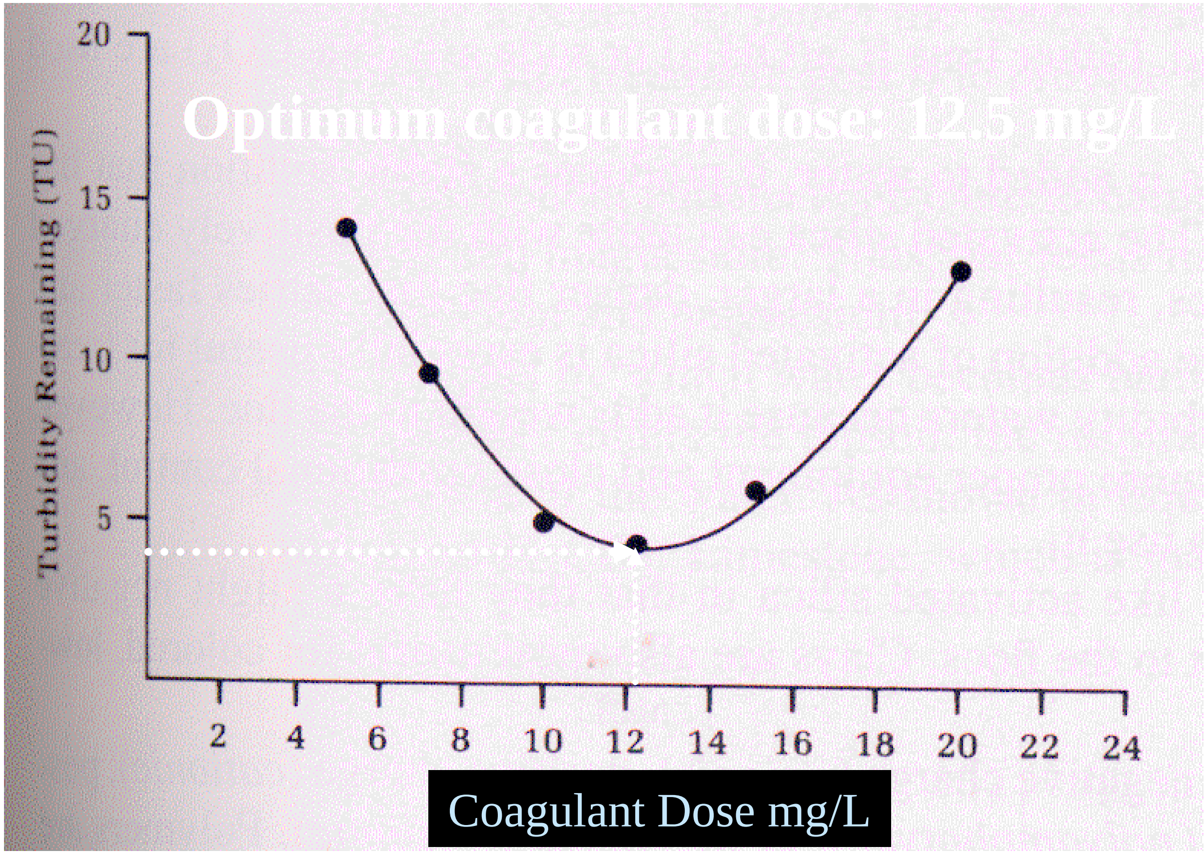


- Add different doses of the selected coagulant (alum or iron) to each jar (Coagulant dose: 5; 7; 10; 12; 15; 20 mg/L)
- Rapid mix each jar at 100 to 150 rpm for 1 minute. The rapid mix helps to disperse the coagulant throughout each container
- Reduce the stirring speed to 25 to 30 rpm and continue mixing for 15 to 20 mins

This slower mixing speed helps promote floc formation by enhancing particle collisions which lead to larger flocs

- ❑ Turn off the mixers and allow flocs to settle for 30 to 45 mins
- ❑ Measure the final residual turbidity in each jar
- ❑ Plot residual turbidity against coagulant dose

The coagulant dose with the lowest residual turbidity will be the optimum coagulant dose

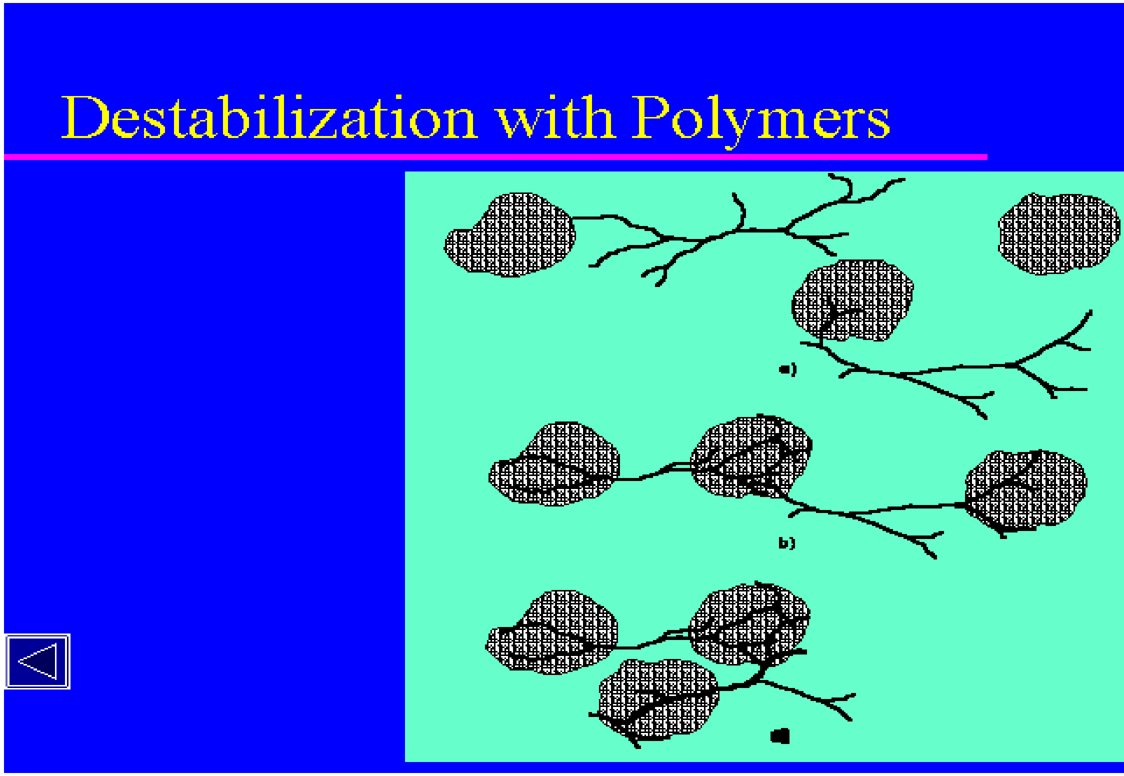


COAGULANT AIDS

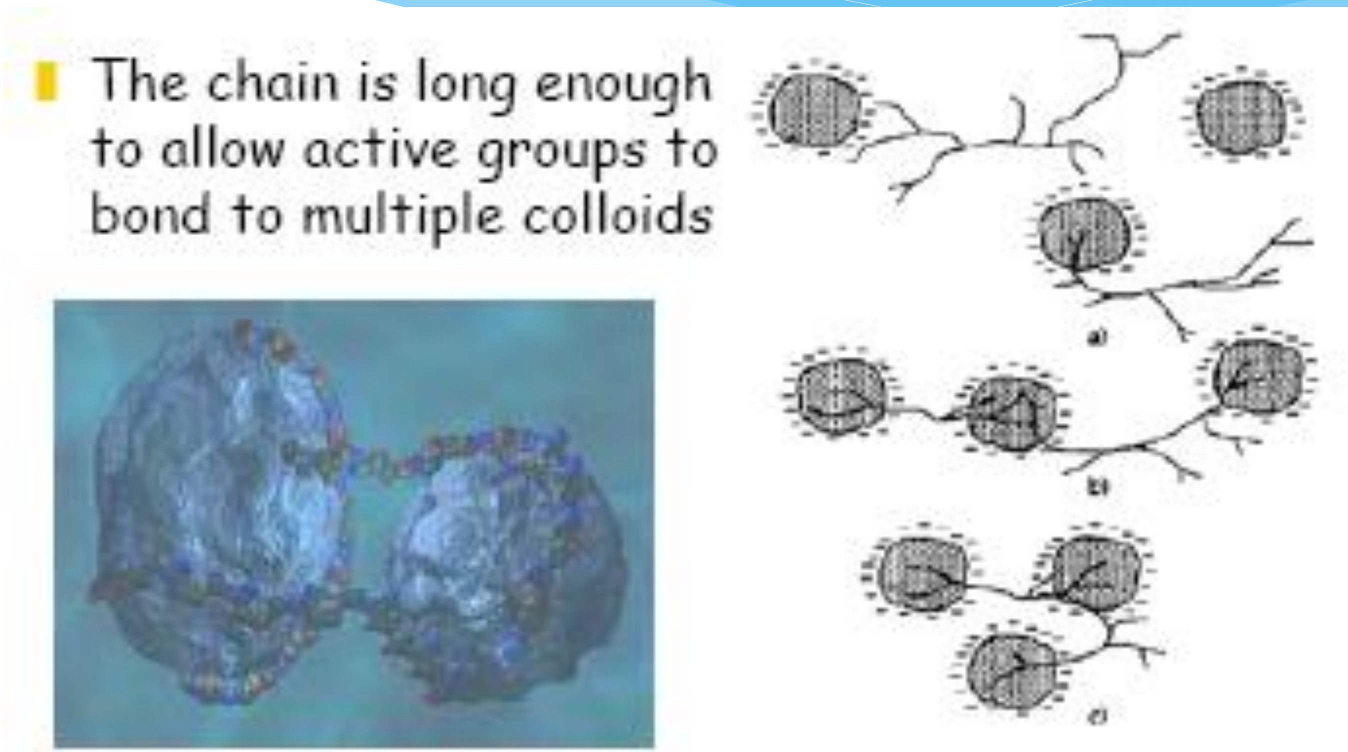
Other substances than coagulants used:

- Clay minerals
- Silicates
- Polymers

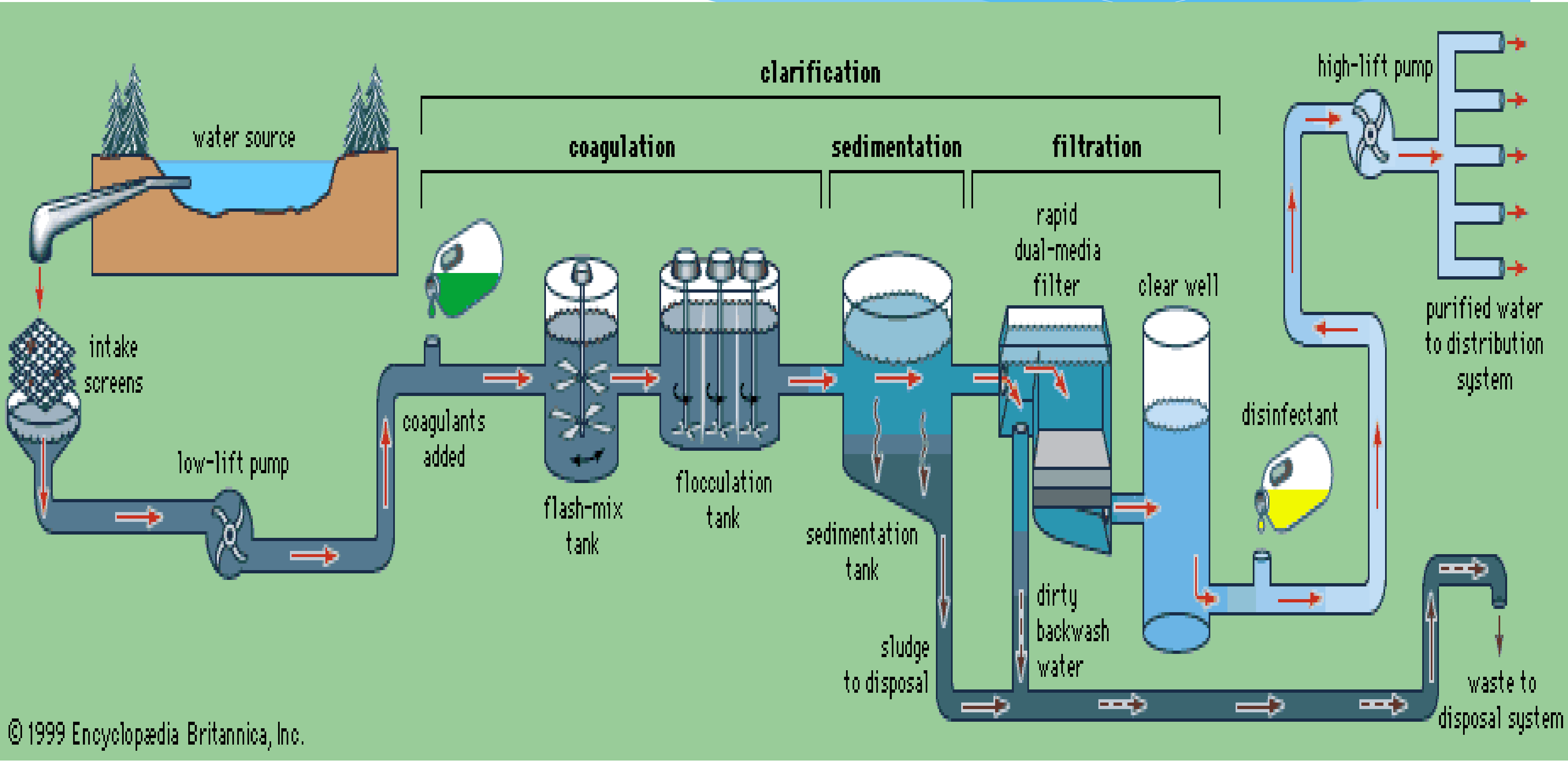
Polymers are often either anionic or cationic to aid coagulation. Polymers also reinforce flocs



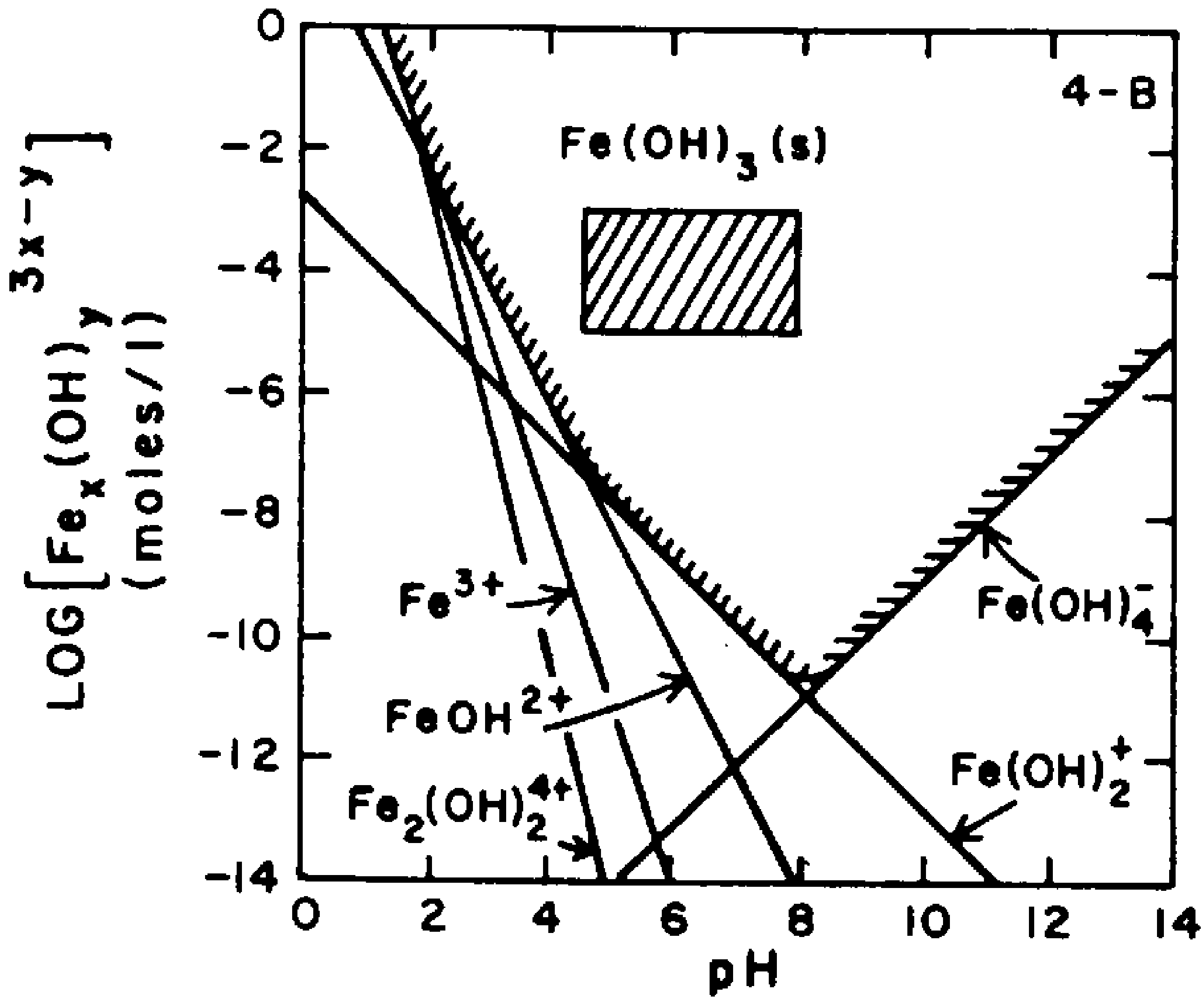
Flocculation aids



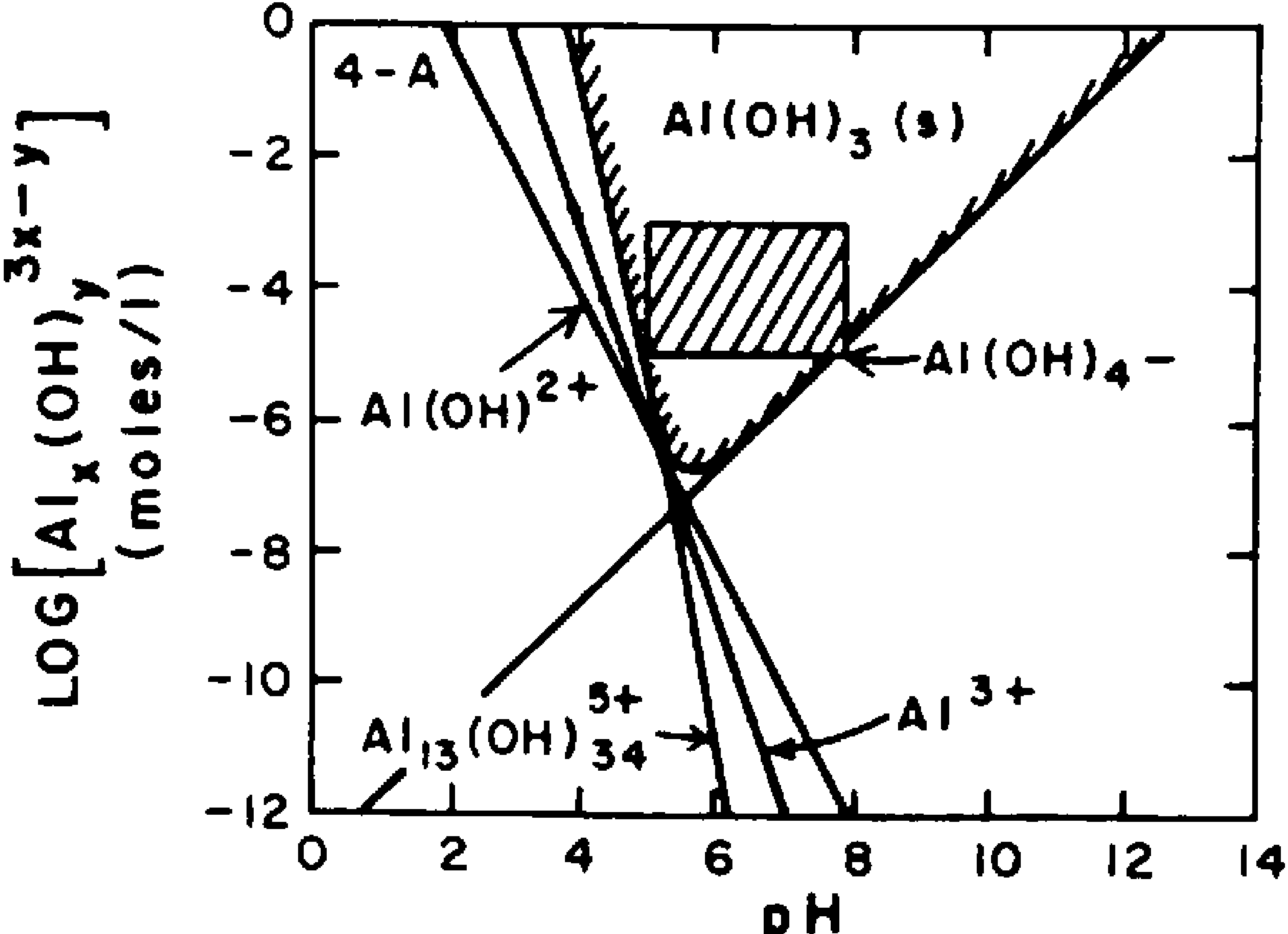
Flocculation and its applications in water treatment



Typical layout of a water treatment plant

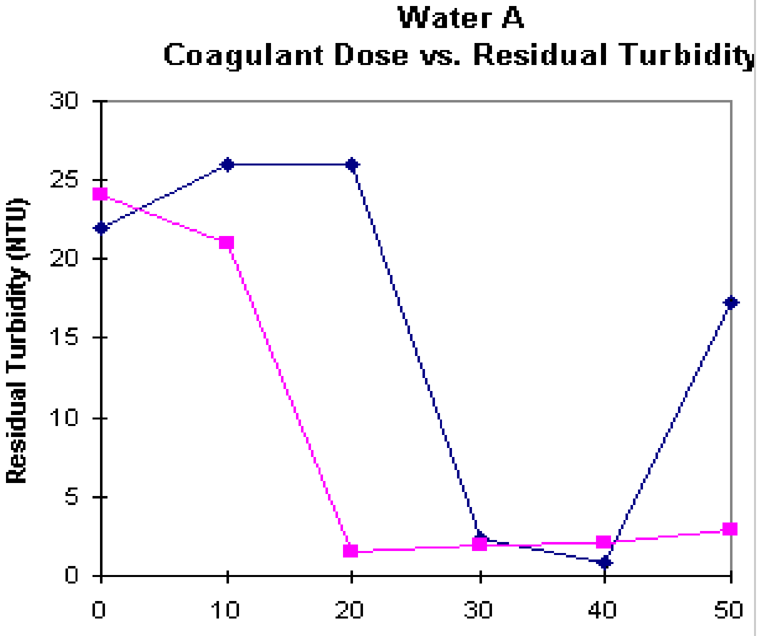


Fe(III) EQUILIBRIA

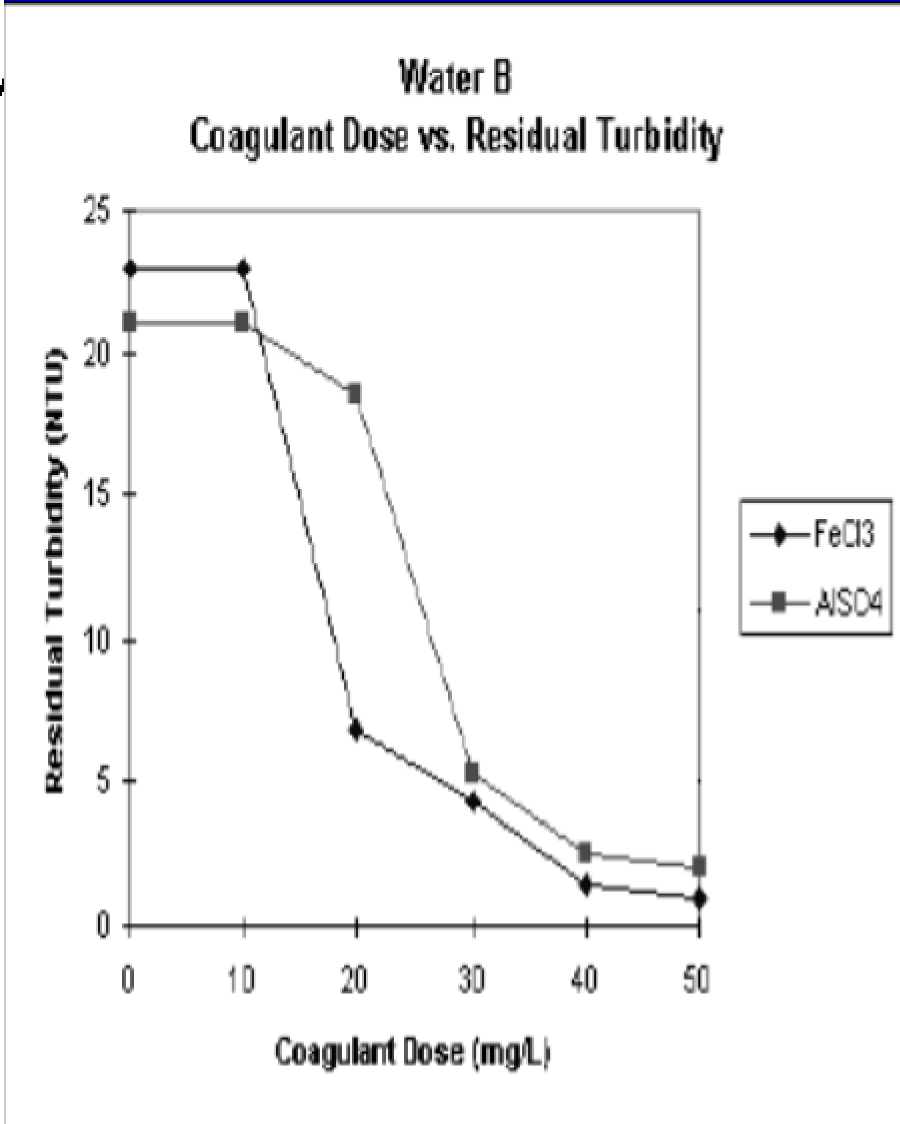


Al(III) EQUILIBRIA

Typical results from a jar test series might look like:

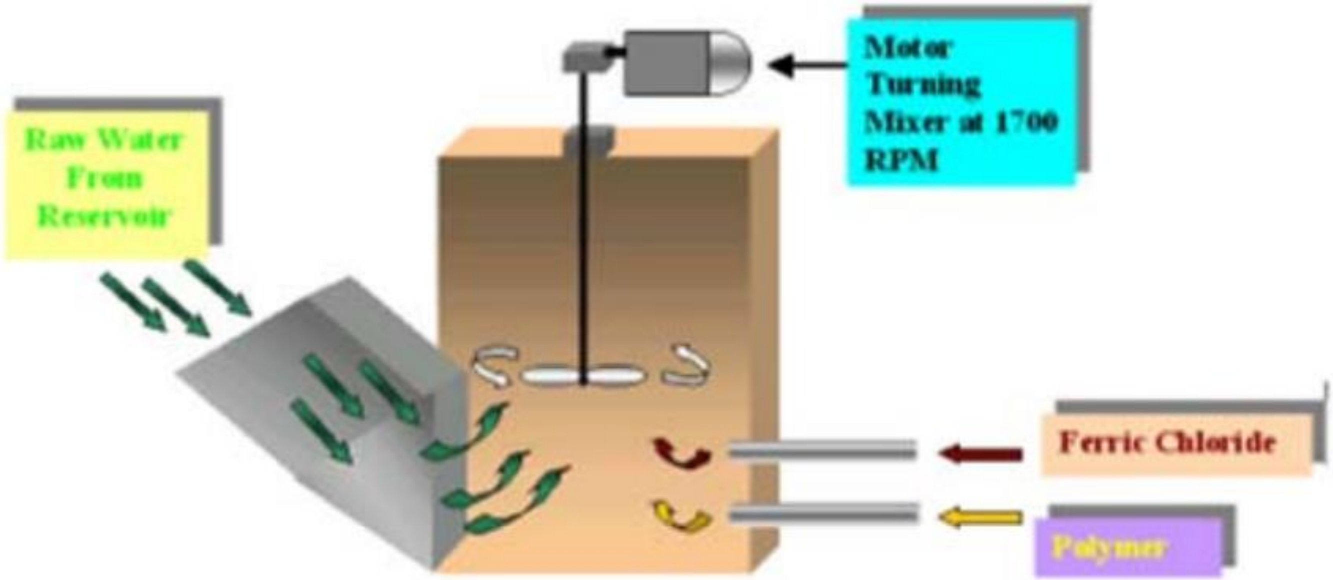


Dose (mg/L)



Rapid Mixing

- Prior to entering a flocculation tank, the water flows through a rapid mixing basin. Chemicals are injected just before the first mixing impeller and baffles throughout the basin to minimize short-circuiting.



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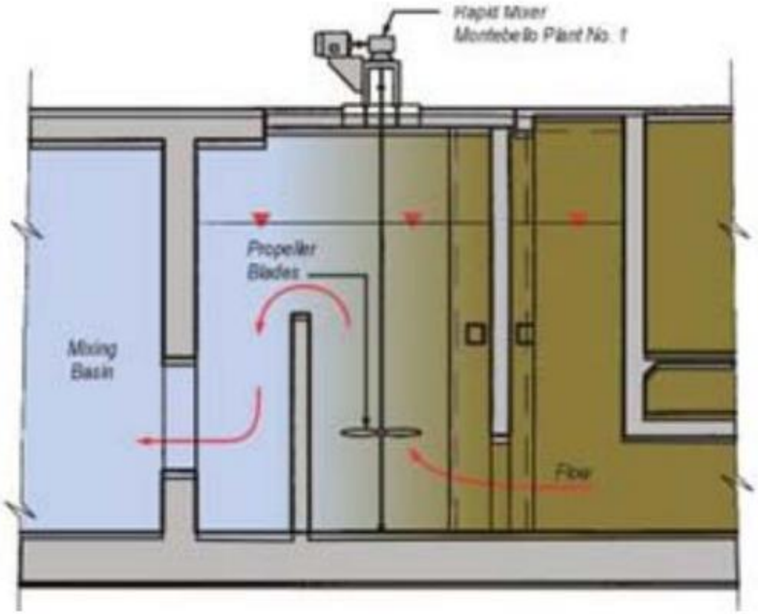
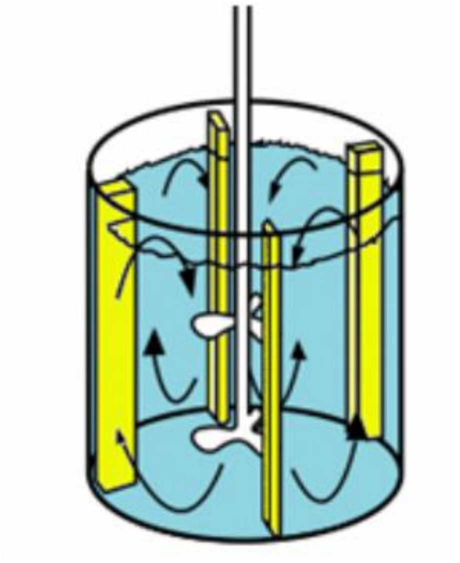
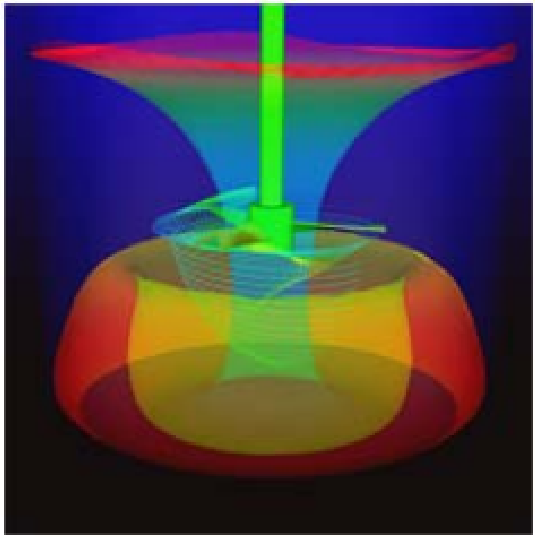




Flocculation

- Flocculation is gentle mixing to speed the agglomeration of colloidal materials.

- The water enters a small tank or section of a tank in which paddles are turning slowly. Their movement causes the small particles to collide and stick together (fast or vigorous mixing would separate combined particles).



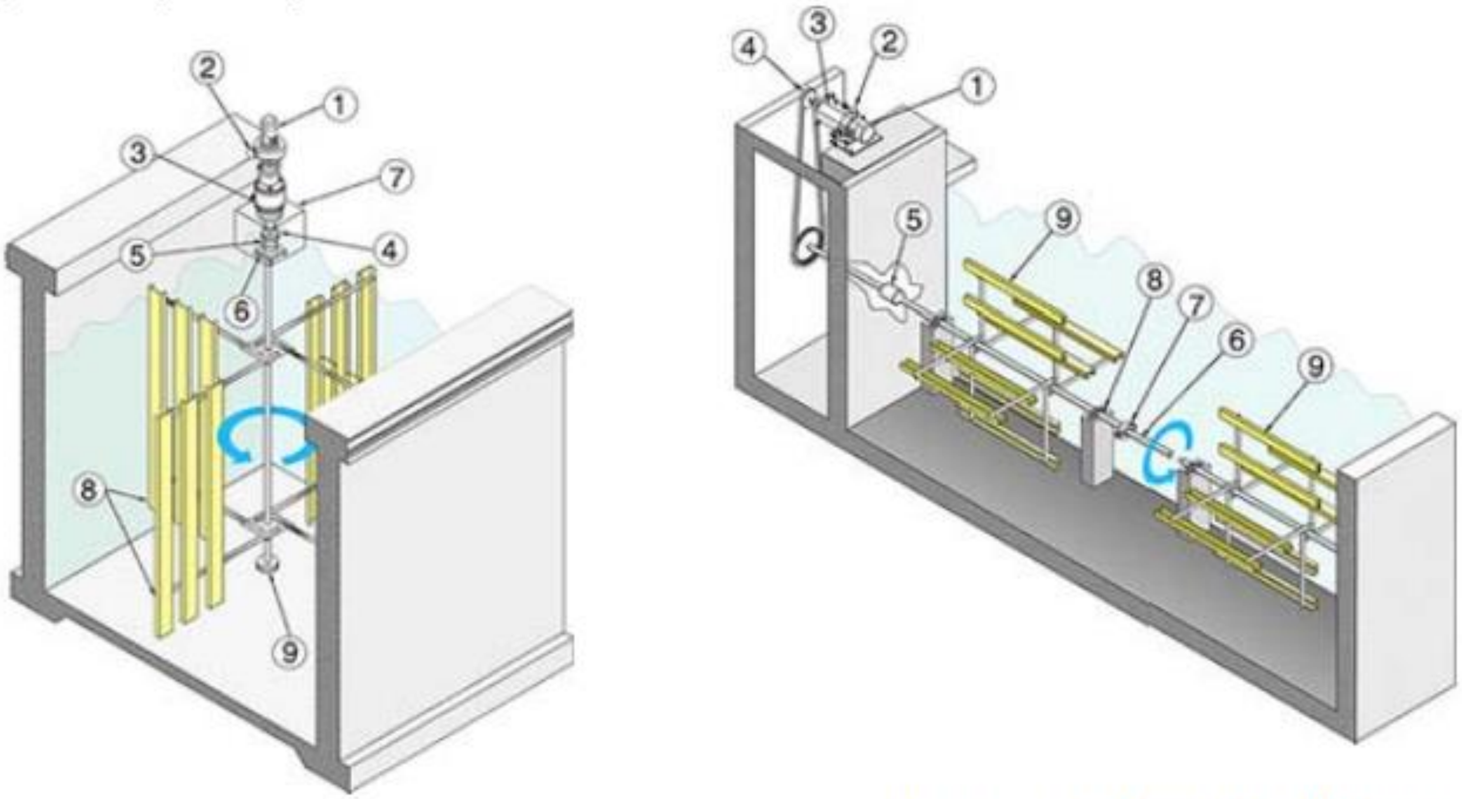
Flocculation

- Doubling the particle diameter increases its settling velocity by a factor of 4.
- The water then flows into the sedimentation basin where the solids settle to the bottom and are removed.

Flocculation

Flocculation

Graphic courtesy of Jim Myers & Sons, Charlotte, NC



Vertical Paddle Wheel

Horizontal Paddle Wheel